Art II.—*Note on the Deposition of Bedded Tuffs.*

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(With Plate II.).

[Read 11th April, 1907].

In many, if not most, of the places in South-western Victoria where tuffs are displayed they are well stratified. These tuffs are associated with the basaltic lavas which form such a feature of the geology of the State, and are referable to various parts of the tertiary period. The volcanic rocks cover, according to Selwyn, somewhere about 9000 square miles, or about a tenth of the total area of Victoria.

The tuffs with which we are at present concerned are usually fawn-coloured, and vary with considerable irregularity in the size of their constituent grains. They show a tendency to split into flags along their bedding planes, and are fairly coherent, so that they are used, as in the neighbourhood of Camperdown, as a rough building stone.

The decomposition of the tuffs and of the coarser scoria yields a remarkably rich soil, and the porous subsoil affords both natural drainage and a capacity for storing up water. The tuffs are then commonly tree-clad.

Among the places which have come under my notice where well bedded tuffs are to be seen are two belonging to the older volcanic series, which is here seen to underlie the marine Barwonian beds. One of these is at Curlewis, about eight miles east of Geelong, where on the beach platform a continuously dipping series is seen extending for about four miles. The basalt of similar age at Airey's Inlet is also associated with well bedded tuffs which dip inland from the shore, pointing to the old vent having been out at sea.

Among the more recent tuffs which also show this character may be enumerated those of Mount Leura and Bullenmerri, near Camperdown. These beds cover a very large area. On the

flanks of Tower Hill, as the railway runs down through cuttings towards Warrnambool, well stratified tuffs are extensively displayed. There is a similar well bedded tuff, though only a few feet in thickness, overlying the Kalimnan at "McDonald's" on Muddy Creek, near Hamilton. Quite recently I have seen many square miles of equally well bedded tuffs about Mount Gambier in the south-east corner of South Australia, and to these attention will be more fully directed later.

Similar, though usually obscure, bedding is shown in the scoria on the flanks of Mount Leura. The great banks have been extensively worked for many years for railway ballast and for covering footpaths, so that ever changing sections were displayed.

Though bedding appears extremely common in the tuffs, it is not universal, and I call to mind a section shown in a road cutting near the Park gates at Camperdown where bedded tuffs show a faulted contact with unstratified ones.

The bedding is generally of such a well marked character that rough flags can be quarried almost everywhere.

The question arises, To what is this bedding due? Was the deposition subaqueous or merely subaerial? Till recently I never thought of the possibility of anything but subaerial deposition being suggested in most of the places mentioned. Professor J. W. Gregory[1] holds that the beds round Camperdown are of subaqueous origin, and that the stratification is due to sorting by water. Of the correctness of this view I have doubts, and I have lately found evidence at Mount Gambier which shows that well bedded tuffs may owe their stratification to subaerial sorting, and hence no reason exists for calling on large lakes or the sea to explain their character.

The assertion of subaqueous deposition for all these tuffs would demand the existence of large bodies of water, either marine or fresh water, extending over very wide areas and at various periods. The well-bedded tuffs of Curlewis and Airey's Inlet are older tertiary age. Those of Koroit, Muddy Creek and Mount Gambier are recent. The Bullenmerri tuffs may be pleistocene. The supposed subaqueous deposition of the tuffs of

1 Geography of Victoria, p. 128.

various ages and localities is the only evidence in favour of the former existence of these seas or lakes, and that, too, at times in peculiar positions in reference to the modern surface drainage.

Then, again, the tuffs, though stratified and very evenly bedded, are not of uniform grain. Taking a small piece, stratification is not evident. Dust and small scoriaceous fragments seem mingled in confusion. It is the fine matter which brings about the fissility, and yet the amount of commingled larger material is considerable. There are, of course, well marked beds of dust, and equally well marked ones of coarse grain, but to my mind the sorting is not as thourogh as it would have been had water—that is, standing water—been the cause of the bedding.

Mud torrents have been suggested, but they also are, I think, out of the question. Such torrents would, if they formed stratified deposits at all, show false bedding, and not layer after layer through a thickness of many feet, and a lateral measurement of scores of yards.

However, apart from this, we have at Mount Gambier evidence which, I think, shows clearly that tuffs, as well stratified as any of those of the Camperdown district, may occur under conditions which forbid aqueous action.

A brief sketch of the geology of the district is necessary to enable this evidence to be properly weighed.

The bed-rock over hundreds of square miles is a white limestone mainly composed of polyzoal remains. This is of Barwonian age (*?* Eocene), and is, as far as can be seen, quite horizontal. It is extremely porous, and water-courses are absent. There are, of course, many swallow holes, caves and underground drainage channels, so that many of the irregularities of the surface are undoubtedly due to subterranean solution. This point may be considered unfavourable to my view, so that I wish to be properly considered. The general surface of the country is slightly undulating, and the hills to the north of the town are, for the most part, sandy. They are, in fact, sand dunes of pleistocene or recent age, and vary somewhat in the amount of lime they contain, and consequently in the amount of consolidation they have undergone. In places they are loose yellow sands, and in other places consist of the ordinary cross-bedded dune-rock. A few miles to the south of the town similar dune-

rock forms the surface, and the typical form of the cups so characteristic of dunes is easily traced. In other places we find long, branching and anastomosing ridges, the dune-rock being frequently capped by the white so-called travertine, the residue of evaporated ground water.

We thus have two limestones, the lower one a marine, polyzoal-rock, and the upper an aeolian one. The marine limestone affords a richer soil, and at the same time flints are commonly scattered on the surface, while they are not found in the dune-rock. So that the presence of flints is a key to the underlying rock.

It will be seen that a large number of the low ridges and hills cannot be ascribed to subterranean denudation, for in the flats and valleys between them flints often occur, and swallow holes and caves are common. The hills are isolated, or practically isolated ridges of calcareous, wind-borne sand. It is essential that this fact be insisted on, and I paid attention to it in several places in the district. The dunes extend inland for many miles, and probably lose their marine origin as they pass north through the mallee country.

A mile to the south of the town of Mount Gambier occurs the mount itself, a volcanic pile. There has been practically no effusion of lava. A sheet of it is seen inside the shattered crater walls, and was the first material ejected. The tuffs extend for two or three miles round the foot of the mount, and are of no great thickness.

A little more than a mile south of the mount is a long east and west ridge of dune rock. This rises some fifty feet above the surrounding country, and is crossed by two roads, one going south to Port Macdonnell, and the other a couple miles east of it, leading to Nelson at the mouth of the Glenelg river. Both these roads pass through cuttings about twelve feet deep and show dune rock capped by tuffs. The tuffs are well-bedded, quite as distinctly and as evenly as anything shown about Camperdown. They, moreover, show a marked peculiarity in that they follow the contour of the ground closely. It is not a case of a tuff capping the hill and being missing on the flanks. The bedding planes are parallel to the present surface. They rise from the north, cross the ridge and sink down towards the

south, forming a blanket-like covering of even thickness, which is quite unbroken.

This feature is diagrammatically shown on the two roads mentioned, and, after noting them from the coach, I walked out to the "Corkscrew," as the winding road over the ridge on the Port road is called, and examined the section with care.

The same feature is shown in the town itself. Gray-street, at about a hundred yards north of Commercial-road, crosses a dune ridge about thirty or forty feet high. A thin tuff-sheet follows the contour exactly as in the cases just mentioned. West of this point, about a quarter of a mile, in a street running north from the State school, well-bedded tuffs dip east off an eastward facing slope of dune rock, their dip agreeing with the slope. In this case I did not attempt to trace them over the hill and down the counter slope to the west. In Gray-street, a thin layer of old soil intervenes between the dune-rock and the tuff. Three of these sections are, I think, crucial, and the fourth appears similar to them. It is surely impossible for material to have been deposited from water in this way. At the "Corkscrew," the stratification lines can be traced for a hundred yards, the beds are but the fraction of an inch thick, and there is no thickening of the deposit on the flanks. The whole is perfectly regular. Had the Gray-street hill been under water, the old soil, at any rate, must have been swept away.

Hitherto no reference has been made to the tuffs of other countries. My aim has been to show that the tuffs of south-western Victoria exhibit no characters inconsistent with aerial deposition, and by this, I do not mean that a strong wind-drift took place, for this would produce cross-bedding, a thing I have not seen, but merely a sorting of material raised into the atmosphere, not by wind, but by volcanic explosion.

Professor Judd says[1] :—"Thus the tuffs covering the city of Pompeii are found to consist of numerous thin layers of lapilli and volcanic dust, prefectly distinct from one another, and assuming even the arrangement which we usually regard as characteristic of materials that have been deposited from suspension in water. The fragmentary materials in falling through the air are sorted. . . . ."

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1 "Volcanoes," p. 117.

What is true of these Vesuvian tuffs is true of our Victorian ones, and there is no need to call the agency of water to account for their stratification.

SUMMARY.

1. The well-stratified tuffs of Mount Gambier closely follow the contour of hill and valley, and so could not have been deposited from water.

2. There is no evidence of large bodies of water occurring at different ages throughout Western Victoria, which would be required if the tuffs were subaqueous deposits.

3. Consequently, all our stratified tuffs may be subaerial, and not subaqueous formations.

DESCRIPTION OF PLATE II.

Cutting on road to Port Macdonnell, three miles south of Mt. Gambier. The arch in the bedding of the tuffs on the crown of the hill is clearly visible. The small caves under the tuffs are caused by the removal of the old surface soil by wind. The core of the arch is formed of dune-rock.